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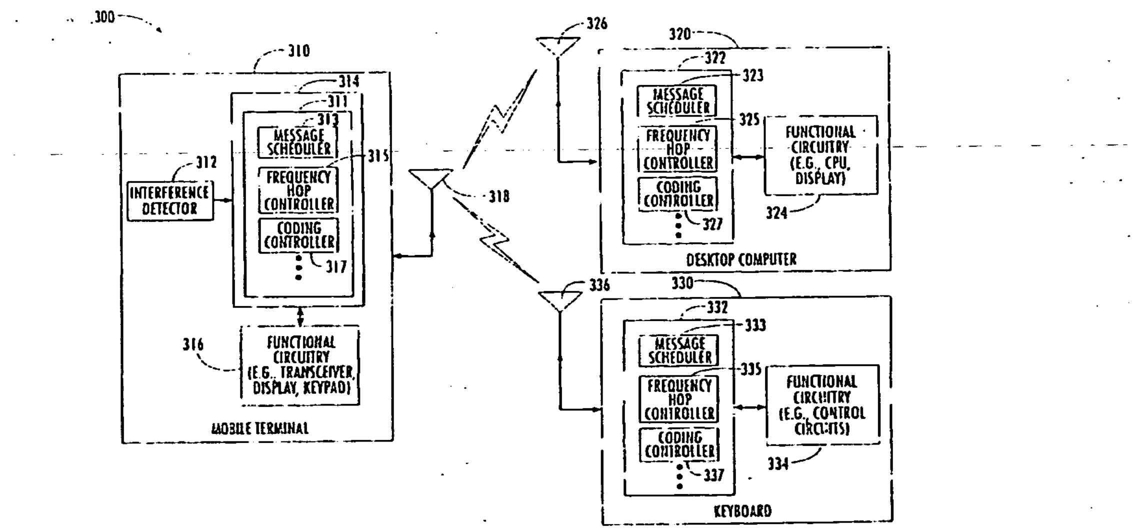
(54) Title: APPARATUS AND METHODS FOR SELECTIVE INTERFERENCE MITIGATION



(57) Abstract: Selective compensation for interference in a communications system, such as a piconet or scatternet using an Industrial-Scientific-Medical (ISM) frequency band, may be achieved, according to embodiments of the present invention, by adapting the interference mitigation scheme applied in a communications system based on comparison with known patterns associated with particular types of interference, such as interference generated by microwave ovens, medical equipment, industrial equipment and wireless communications devices. According to embodiments of the present invention, a communications system, such as wireless communications system, detects interference and changes from a first interference mitigation scheme to a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference, such as the half-cycle pulsed pattern typical of a microwave oven.

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APPARATUS AND METHODS FOR SELECTIVE INTERFERENCE MITIGATION

BACKGROUND OF THE INVENTION

The present invention relates to communications apparatus (systems) and methods, and more particularly, to interference mitigation apparatus and methods used in communications systems.

Wireless communications techniques are widely used to convey information in voice telephony, paging, data transfer and a host of other applications. One use of wireless communications techniques is in low-power, short-range communications, e.g., communications between devices located within a room, home, automobile passenger compartment, or other relatively small area. For example, communications protocols, such as the Bluetooth™ set of protocols and the IEEE 802.11 protocols, have been developed that utilize a portion of the electromagnetic spectrum known as the Industrial-Scientific-Medical (ISM) band, a band of frequencies that are typically used by devices such as microwave ovens and other radio-frequency (RF) heating devices, ultrasonic humidifiers and jewelry cleaners, medical imaging devices such as magnetic resonance imaging (MRI) systems, and a variety of other industrial, scientific and medical equipment. As illustrated in FIG. 1, using such protocols and associated hardware and/or software, devices such as a mobile terminal (e.g., cellular telephone), desktop computer **20**, laptop computer **30**, printer **40**, keyboard **50** and mouse **60** may be interconnected via radio links **5**, forming one or more systems or networks, sometimes referred to as "piconets" or "scatternets," over which voice and other information may be exchanged.

A potential problem associated with communications in a system using an ISM band is that such a band is typically used in a loosely regulated fashion by both communications devices and non-communications devices. For example, in the United States, rules established by the Federal Communications Commission "regulate" the ISM band such that no particular user is granted possession of a particular frequency or set of frequencies, as it is envisioned that the ISM band will be used by devices with limited transmit power, making such allocation of the airwaves unnecessary and/or undesirable. Consequently, in a given environment, there is a likelihood that a communications system using the ISM band may encounter

interference from other devices using the ISM band, including communications devices, such as garage door opener transmitters or baby monitors, and non-communications devices, such as microwave ovens and industrial RF heating equipment.

Conventional communications systems that use the ISM band commonly implement some type of interference mitigation scheme to reduce the deleterious effects of interference. For example, the aforementioned Bluetooth™ protocol set specifies use of a frequency-hopping scheme wherein a system of devices switches through a predetermined set of carrier frequencies at a predetermined rate to reduce interference, and provides for further interference mitigation through optional use of forward error correction coding. Other techniques, such as retransmission techniques, may also be used to reduce negative effects of interference. However, such conventional interference mitigation techniques may be less effective than desired in the presence of strong in-band interference from devices designed to utilized the same frequency band as the communications system. Accordingly, there is a need for improved methods and apparatus for interference mitigation.

SUMMARY OF THE INVENTION

The present invention may meet this and other needs by tailoring the selection of interference mitigation schemes based on comparisons with predetermined interference patterns. According to embodiments of the present invention, selective compensation for interference in a communications system, such as a piconet or scatternet using an Industrial-Scientific-Medical (ISM) frequency band, may be achieved by adapting the interference mitigation scheme applied in the communications system based on known patterns associated with particular types of interference, such as interference patterns typically exhibited by microwave ovens, industrial equipment and communications devices. According to embodiments of the present invention, a communications system, such as wireless communications system, detects interference and changes from a first interference mitigation scheme to a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with a predetermined pattern associated with a predetermined type of interference, such as the half-cycle pulsed pattern typical of a microwave oven.

According to other embodiments of the present invention, the communications system applies the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference. For example, the communications system may predict an interval of increased interference based on the predetermined pattern, e.g., an interval in which a microwave oven pulse is predicted to be present. The communications system may choose to perform a variety of actions based on the prediction, including foregoing transmission of messages during the predicted interval, changing coding of messages transmitted during the predicted interval, foregoing transmission of messages to a selected device of the communications system during the predicted interval and foregoing use of a selected frequency to communicate messages during the predicted interval.

According to other embodiments of the present invention, a communications system includes at least one communications device operative to communicate via a communications medium. The communications system also includes an interference detector that detects interference in the communications medium. The communications system further includes an interference mitigation controller, operatively associated with the at least one communications device and responsive to the interference detector circuit, that causes the at least one communication device to change from using a first interference mitigation scheme to using a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with a predetermined pattern associated with a predetermined type of interference. The at least one communications device may include a communications circuit, and at least one of the interference detector and the interference mitigation controller may be operatively associated with the communications circuit. For example, the interference detector circuit may be responsive to the communications circuit to detect interference. According to other embodiments of the present invention, the at least one communications device includes a plurality of communications devices, the interference detector includes at least one interference detector circuit positioned at at least one of the plurality of communications devices, and the interference mitigation controller includes at least one interference mitigation controller circuit positioned at at least one of the plurality of communications devices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating a system of wireless communications devices according to the prior art.

FIGs. 2-5 are schematic diagrams illustrating communications systems according to embodiments of the present invention.

FIG. 6 is a flowchart illustrating exemplary interference mitigation operations according to an embodiment of the present invention.

FIG. 7 is a schematic diagram illustrating interference mitigation control apparatus according to another embodiment of the present invention.

FIGs. 8-10 are state diagrams illustrating exemplary interference mitigation operations according to embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like numbers refer to like elements.

Referring to FIG. 2, a communications system **200** according to embodiments of the present invention includes a plurality of communications devices **210**, an interference mitigation controller **230** and an interference detector **220**. The interference detector **220** is operative to detect interference in a communications medium **240** used by the communications devices **210**. The interference mitigation controller **230** is responsive to the interference detector **220**, and operatively associated with the plurality of communications devices **210** such that it causes the communication devices **210** to change from using a first interference mitigation scheme, e.g., a first combination of a frequency hopping sequence, error correction coding and message scheduling, to using a second interference mitigation scheme, e.g., a second combination of frequency hopping sequence, error correction coding and message scheduling, if interference detected by the interference detector **220** is sufficiently correlated with predetermined pattern associated with a predetermined type of interference. The predetermined pattern may take the form, for example, of a

pattern, e.g., a pattern generally associated with a known type of device, such as a microwave oven or RF heating device, programmed or otherwise stored in the interference mitigation controller **230**,. The predetermined pattern may also be identified *in situ*, e.g., by processing interference data collected by the interference detector **220** and identifying the pattern therefrom.

The present invention arises from the realization that certain types of interference, such as interference produced in a network using a frequency band that also is used by devices such as microwave ovens or garage door openers, often exhibits behavior that is predictable. For example, a typical microwave oven produces microwave radiation every other half-cycle of the frequency of the AC power line that powers the oven. Similarly, a device such as garage door opener transmitter typically produces interference in bursts of predetermined duration. Other types of interference may also be identified *in situ* by processing interference data and identifying repetitive patterns therein. Accordingly, improved interference mitigation measures may be adopted that utilize these types of *a priori* knowledge of interference.

It will be appreciated that although FIG. 2 illustrates application of the present invention to a wireless communications environment, the scope of the present invention is not so limited. It will be appreciated that the present invention is applicable to a variety of types of communications, including, but not limited to radio, wireline and optical communications. Although FIG. 2 conceptually illustrates the interference detector **220** and the interference mitigation controller **230** as separate from the communications devices **210**, it will also be readily appreciated that the present invention is not limited to such a configuration. It will be understood that, generally, functions of the communications devices **210**, the interference detector **220** and the interference mitigation controller **230** may be implemented in separate devices, distributed among several devices, or combined, all or in part, in a single device.

FIG. 3 illustrates a wireless communications system **300** according to embodiments of the present invention, specifically, a wireless communications system in which interference detection and interference mitigation control functions are integrated into wireless communications devices, here a mobile terminal (e.g., cell phone) **310**, a desktop computer **320**, and a keyboard **330**. As shown, the desktop computer **320** includes functional circuitry **324**, such as a central processing unit

(CPU) and display control circuitry. Similarly, the keyboard includes functional circuitry 334, such as control circuits that monitor and control keyboard operations. The personal computer 320 and the keyboard 330 include respective communications circuits 322, 332 that provide radio communications (e.g., provide a radio link between the desktop computer 320 and the keyboard 330) via respective antennas 326, 336. As shown, the communications circuits 322, 332 include interference mitigation related circuits such as message scheduler circuits 323, 333 that control timing of message transmission, frequency hop controller circuits 325, 335 that control carrier frequencies at which messages are transmitted and/or received, and coding controller circuits 327, 337 that control error correction coding and decoding operations. It will be appreciated that the communications circuits 322, 332 may include other interference mitigation related circuits, as well as circuits involved in other aspects of providing a wireless communications interface.

The mobile terminal 310 includes functional circuitry 316, such as radio transceiver circuitry, display control circuitry, and keypad interface circuitry. The mobile terminal 310 also includes a communications circuit 314 that implements a wireless communications interface (e.g., radio links to the desktop computer 320 and the keyboard 330) for the mobile terminal 310 via an antenna 318. The communications circuit 314 includes an interference mitigation controller circuit 311, here shown as including a message scheduler circuit 313, a frequency hop controller circuit 315 and a coding controller circuit 317. The mobile terminal 310 further includes an interference detector circuit 312 that is operative to detect interference in a communications medium in which the communications circuits 314, 322, 332 communicate. The interference mitigation controller circuit 311 is responsive to the interference detector circuit 312 to control the interference mitigation scheme, for example, the particular combination of message scheduling, frequency hopping, and error control coding, applied by the communications circuits 314, 322, 332.

It will be appreciated that the interference detector circuit 312 may operate and be implemented in a number of different ways. For example, as suggested by FIG. 3, an interference detector circuit 312 may be implemented as a standalone circuit, positioned in a particular device, that detects interference in the communications medium used by the communications circuits 314, 322, 332 independently of these circuits. However, it will be appreciated that the functions of the interference detector circuit 312 may also be integrated with other functions of the communications circuits

314, 322, 332. For example, the interference detector circuit **312** may monitor radio communications of the communications circuit **314**, and may use such measures as bit error rate estimates, numbers of unacknowledged messages, and the like generated by the communications circuit **314** to detect the presence of interference.

It will also be appreciated that the interference mitigation controller circuit **311** may also be implemented in a number of different ways. For example, functions of the interference mitigation controller circuit **311** may be localized within a particular device, e.g., within the communications circuit **314** of the mobile terminal **310**, or may be distributed among multiple devices and/or circuits.

The interference mitigation controller circuit **311** may also operate in a number of different ways. For example, responsive to detection of interference by the interference detector **312**, the interference mitigation controller circuit **311** may analyze the detected interference using analog or digital signal comparison techniques. The interference mitigation controller circuit **311** may compare the detected interference, for example, to a "library" of known patterns that are preprogrammed into the interference mitigation controller circuit **311** and/or which are identified *in situ* by the interference mitigation controller circuit **311** responsive to interference detected by the interference detector circuit **312**. If the comparison indicates sufficient correlation between the detected interference and a pattern associated with a predetermined type of interference, e.g., a half-wave pulsed pattern characteristic of a typical microwave oven or a pattern identified *in situ* by processing interference detected by the interference detector circuit **312**, the interference mitigation controller circuit **311** may selectively implement an interference scheme in accord with the predetermined pattern associated with the predetermined type of interference. For example, the interference mitigation controller circuit **311** may cause the communications circuit **314** to transmit appropriate messages to communications circuits **322, 332** in the desktop computer **320** and the keyboard **330** to cause these devices to, for example, forego transmitting messages during intervals in which interference is predicted to be most intense, to avoid using a particular frequency during such an interval, or to apply a more robust level of error correction coding during such an interval.

FIG. 4 illustrates a wireless communications system **400** according to other embodiments of the present invention, in which interference detection and mitigation control functions are distributed in a different manner than illustrated in FIG. 3. A

first communications device, here a mobile terminal 410, includes functional circuitry 416 such as transceiver, display and keypad circuits. The mobile terminal 410 also includes a communications circuit 414 that provides a wireless communications interface via an antenna 418. The communications circuit 414 includes an interference mitigation controller circuit 411, here shown as including message scheduler circuit 413, a frequency hop controller circuit 415 and a coding controller 417 circuit, operatively associated with an interference detector circuit 412.

A second wireless communications device, here a desktop computer 420, includes functional circuitry 426, such as CPU and display circuits. The functional circuitry 426 is operatively associated with a communications circuit 424 that provides a wireless communications interface via an antenna 428. The communications circuit 424 includes an interference mitigation controller circuit 421, here shown as including message scheduler circuit 423, a frequency hop controller circuit 425 and a coding controller circuit 427. The interference mitigation controller circuit 421 is operatively associated with an interference detector circuit 422.

According to embodiments of the present invention, wireless communications devices, such as the mobile terminal 410 and the desktop computer 420 of FIG. 4, can implement selective interference mitigation in a number of different ways. For example, in devices conforming to a protocol such as Bluetooth™, each of the communications circuits 414, 424 may operate as a master device or a slave device in a piconet or similar system. Accordingly, for example, upon detection of interference by one of the interference detector circuits 412, 422, the interference mitigation controller circuit 411, 421 of one of the communications circuits 414, 424 that is currently serving as "master" may determine if the detected interference is sufficiently correlated with a pattern associated with a known type of interference. If so, the master interference mitigation controller circuit 411, 421 may instruct one or more of the message scheduler circuits 413, 423, frequency hop controller circuits 415, 425, and coding controller circuits 417, 427 to use a new interference mitigation scheme, for example, to implement a new combination of message scheduling, frequency hopping and/or error correction coding. It will appreciated that, in general, the communications system 400 may be viewed as providing individual interference detector and interference mitigation controller circuits in each device 410, 420 of the communications system 400, or as providing interference detector and/or interference mitigation controller circuits that are distributed across multiple devices.

FIG. 5 illustrates a communications system **500** according to other embodiments of the present invention that illustrates how such distributed interference detection and interference mitigation control may be implemented. A first wireless communications device, here a mobile terminal **510**, includes functional circuitry (not shown for clarity of illustration), such as circuitry that controls and/or monitors display, keypad, and wireless telephony functions. The mobile terminal **510** includes a communications circuit **514** which provides a communications interface via an antenna **520**. The communications circuit **514** includes a processor **518**, e.g., a microprocessor, microcontroller, or other data processing circuit, that is operatively associated with a radio transceiver **519** and a memory **516**. An interference detector **512** is implemented as software or firmware routine (e.g., a portion of a "software stack") stored in the memory **516** and executed by the processor **518** to control and/or monitor the radio transceiver **519**. Similarly, an interference mitigation controller **511** is implemented as a set of software routines, e.g., message scheduling, frequency hop control, and coding control routines **513**, **515**, **517**, stored in the memory **516** and executed by the processor **518**. For example, the message scheduling, frequency hop control, and coding control routines **513**, **515**, **517** of the interference mitigation controller **511** may be operative to cause the processor **518** to compare interference detected by the interference detector **512** with a pattern associated with a known type of interference and, if the detected interference is sufficiently correlated with the pattern of the known type of interference, to cause the processor **518** and the transceiver **519** to change to use of a particular interference mitigation technique. This may include, for example, causing the processor **518** and the transceiver **519** to send appropriate messages to command other devices to use a particular interference mitigation scheme.

A second wireless communications device, here a laptop computer **530**, includes functional circuitry (not shown for clarity of illustration), such as circuitry that controls and/or monitors display, keypad, and other functions. The laptop computer **530** includes a communications circuit **534** that provides a communications interface via an antenna **540**. The communications circuit **534** includes a processor **538**, e.g., a microprocessor, microcontroller, or other data processing circuit, that is operatively associated with a radio transceiver **539** and a memory **536**. An interference detector **532** is implemented as software or firmware routine (e.g., a portion of a "software stack") stored in the memory **536** and executed by the

processor 538 to control and/or monitor the radio transceiver 539. Similarly, an interference mitigation controller 531 is implemented as a set of software routines, e.g., message scheduling, frequency hop control, and coding control routines 533, 535, 537 stored in the memory 536 and executed by the processor 538. For example, the message scheduling, frequency hop control, and coding control routines 533, 535, 537 of the interference mitigation controller 531 may be operative to cause the processor 538 to compare interference detected by the interference detector routine 532 with a pattern associated with a known type of interference and, if the detected interference is sufficiently correlated with pattern associated with the known type of interference, to cause the processor 538 and the transceiver 539 to change to use of a particular interference mitigation technique. This may include, for example, causing the processor 538 and the transceiver 539 to send appropriate messages to command other devices to use a particular interference mitigation scheme.

Interference detection and mitigation functions of the communications system 500 of FIG. 5 may be implemented in a number of different ways. For example, in a master/slave environment, one of the communications circuits 514, 534, acting as a master, may determine whether interference detected by one or more of the interference detector routines 512, 532 is correlated to a pattern of a predetermined type of interference, and may dictate the appropriate interference mitigation scheme to be applied in the communications system 500. It will appreciated that, in general, the communications system 500 may be viewed as providing individual interference detector and interference mitigation controller circuits in each device 510, 530 of the communications system 500, or as providing interference detector and/or interference mitigation controller circuits that are distributed over multiple devices.

FIG. 6 illustrates exemplary operations 600 for providing selective interference mitigation control according to other embodiments of the present invention. A first interference mitigation scheme, for example, a first combination of message scheduling, frequency hopping, and error correction coding, is applied in a communications system such as the communications systems 400, 500 of FIGs. 4 and 5 (Block 610). Interference is detected (Block 620). If the interference is sufficiently correlated to a pattern associated with a known type of interference, such as the half-wave pulsed interference typically produced by a microwave oven, the communications system changes to using a second interference mitigation scheme, e.g., a second combination of message scheduling, frequency hopping and error

correction coding (Block 630). If not, the communications system continues to use the first interference mitigation scheme (Block 610)

It will be appreciated that the operations of FIG. 6 may be implemented in a number of different ways within the scope of the invention. For example, a change in message scheduling may include changing the routing of and/or foregoing transmission of messages during intervals in which interference is predicted to be of higher intensity. For example, a communication system may suspend transmission of messages between devices during an interval in which interference is predicted to be of increased intensity. In other embodiments, if a particular device in a communications system is near a source of interference, the communications system may avoid sending messages to that particular device during a predicted interval of increased interference. Similarly, a change in frequency hopping may include avoiding the use of a particular frequency during a predicted interval of increased interference. A change in coding may include changing to a more robust (e.g., redundant) error correction coding during a predicted interval of increased interference.

FIG. 7 illustrates an interference mitigation controller circuit **720** according to embodiments of the present invention, in which detected interference is compared to a pattern associated with a known type of interference. The interference mitigation controller circuit **720** includes a pattern comparing circuit **724** that is responsive to an interference detector circuit **710**. The pattern comparing circuit **724** compares interference detected by the interference detector circuit **710** with a predetermined pattern **726**, and controls interference mitigation circuitry, such as message scheduler circuit **723**, a frequency hop controller circuit **725** and a coding controller circuit **727**, responsive to the comparison. It will be appreciated that interference detector circuit **710** and the interference mitigation controller circuit **720** may be implemented using a variety of hardware, software and combinations thereof. For example, the interference detector circuit **710** and the interference mitigation control circuit **720** may be implemented within a communications circuit, such as the communications circuits **414**, **424**, **514**, **534** of FIGs. 4 and 5.

FIG. 8 is a state diagram **800** illustrating exemplary operations of a communications system according to embodiments of the present invention. In a first state **810**, a first interference mitigation scheme is applied. Upon detection of interference, the communications system transitions to a second state **820**, in which

the communications system determines the degree of correlation between the detected interference and a pattern associated with a predetermined type of interference. If the interference is insufficiently correlated with the pattern associated with the predetermined type of interference, the communications system transitions back to the first state **810**. If the interference is sufficiently correlated, however, the communications system transitions to a third state **830**, in which the communications system predicts an interval in which the interference is expected to occur. After this interval is predicted, the communications system transitions to a fourth state **840** in which the system applies the second interference mitigation scheme for the predicted interval.

Upon expiration of the predicted interval, the communications system transitions back to the first state **810**, in which it returns to using the first interference mitigation scheme. In some cases, for example, in cases in which the predetermined type of interference occurs as a single event, the communications system may then wait until interference is again detected. In other cases, however, the predetermined type of interference may be periodic in nature, exhibiting intermittent intervals of increased intensity. In such cases, the prediction of an interval of interference occurring in the third state **830** may include prediction of a series of interference intervals, e.g., a series of periodically-occurring intervals. Accordingly, when a next predicted interference interval commences, the communications system may transition from the first state **810**, in which the first interference mitigation scheme is applied, to the fourth state **840**, in which the second interference mitigation scheme is applied. Upon the ending of this next predicted interference interval, the communications system returns to the first state **810** and again applies the first interference mitigation scheme.

FIG. 9 is a state diagram **900** illustrating exemplary operations of a communications system according to other embodiments of the present invention, in particular, exemplary operations for providing selective interference mitigation in a communications system subject to an interference source, such as a microwave oven, that exhibits a pattern of interference characterized by periodic intervals of increased intensity. In a first state **910**, a first interference mitigation scheme is applied. Upon detection of interference, the communications system transitions to a second state **920**, in which the communications system determines whether detected interference exhibits a pulsed pattern that correlates with a half-cycle pulsed pattern typical of a

microwave oven magnetron. If the interference does not, the communications system transitions back to the first state **910**. If the interference does sufficiently match this pattern, however, the communications system transitions to a third state **930**, in which the communications system predicts one or more intervals in which increased interference is expect to occur. For example, in this state the communications system may further analyze the detected interference to determine whether it is correlated to a particular cooking mode, e.g., high-power, medium-power, or defrost, which has a particular duty cycle associated therewith. The communications system may then predict corresponding intervals of increased interference accordingly. After these intervals are predicted, the communications system transitions to a fourth state **940** in which it commands devices of the communications system to implement a second interference mitigation scheme, such as by transmitting appropriate command messages that command devices in the system to use a particular frequency hopping sequence (e.g., to avoid particular frequencies) during a predicted interference interval, to avoid sending messages during a predicted interference interval, and/or to employ a certain type of error correction coding during a predicted interference interval. The communications system then transitions to a fifth state **950**, in which it applies the second interference mitigation scheme for the predicted interval.

Upon expiration of the predicted interval, the communications system transitions back to the first state **910**, in which it returns to using the first interference mitigation scheme. In cases in which a single interference interval is predicted, the communications system may then wait until interference is again detected. In cases in which multiple intervals are predicted, however, the communications system may transition from the first state **910** to the fifth state **950** upon commencement of a next predicted interference interval. Upon the ending of this next predicted interference interval, the communications system returns to the first state **910** and again applies the first interference mitigation scheme.

FIG. 10 is a state diagram **1000** that illustrates exemplary operations according to yet other embodiments of the present invention, in particular, operations in which a communication system applies a different selected interference mitigation scheme depending upon whether detected interference is of a predictable or unpredictable type. A device begins in a normal channel operating state **1010**, i.e., a state in which the communications system applies a "baseline" interference mitigation scheme, which may be, for example, a scheme in which little or no interference mitigation is

applied. Upon detection of interference, the communications system moves to a second state **1020** in which it determines whether the detected interference is of predictable type or an unpredictable type. For example, the communications system may compare the detected interference to a pattern of a predictable type of interference to determine if the detected interference is sufficiently correlated to the pattern to conclude that the detected interference is of the predictable type.

If the interference is of an unpredictable type, the communications system moves to a third state **1030** in which it transmits messages to devices of the communications system to command use of an interference mitigation scheme appropriate for combating unpredictable interference. For example, the communications system may assume that the unpredictable type of interference is random in character and may, therefore, command use of an interference mitigation scheme suited to compensating for random interference. When the detected unpredictable-type interference is no longer present, the communications system may then revert to the normal channel operation state **1010**, e.g., by transmitting appropriate messages to the devices of the system to command a return to using interference mitigation measures appropriate to normal channel operation.

If detected interference is of a predictable type, however, the communications system transitions from the second state **1020** to a fourth state **1040**, in which the communications system predicts one or more intervals during which interference can be expected. The system then transitions to a fifth state **1050**, in which it transmits messages to devices of the communications system to command use of an interference mitigation scheme appropriate to the predictable type of interference during a predicted interval. When a predicted interval ends, the communications system reverts to the normal channel operation state **1010**, e.g., by transmitting appropriate messages to the devices of the system to command a return to using interference mitigation measures appropriate to normal channel operation. In the case where multiple interference intervals are predicted, the communications system may again transition to the fifth state **1050**, applying the predictable-type interference mitigation scheme upon commencement of a new predicted interference interval.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

CLAIMS

THAT WHICH IS CLAIMED IS:

1. A method of operating a communications system, the method comprising:

detecting interference; and

changing from a first interference mitigation scheme to a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference.

2. The method according to Claim 1, wherein changing from a first interference mitigation scheme to a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference comprises applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference.

3. The method according to Claim 2, wherein applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference comprises applying the second interference mitigation scheme according to a predetermined periodicity associated with the predetermined type of interference.

4. The method according to Claim 2, wherein applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference comprises:

predicting an interval of increased interference based on the predetermined pattern; and

performing at least one of the following:

foregoing transmission of messages during the predicted interval;

changing coding of messages transmitted during the predicted interval;

foregoing transmission of messages to a selected device of the communications system during the predicted interval; and

foregoing use of a selected frequency to communicate messages during the predicted interval.

5. The method according to Claim 2, wherein applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference comprises:

predicting an interval of increased interference based on the predetermined pattern; and

foregoing transmission of messages during the predicted interval.

6. The method according to Claim 2, wherein applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference comprises:

predicting an interval of increased interference based on the predetermined pattern; and

changing coding of messages transmitted during the predicted interval.

7. The method according to Claim 2, wherein applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference comprises:

predicting an interval of increased interference based on the predetermined pattern; and

foregoing transmission of messages to a selected device of the communications system during the predicted interval.

8. The method according to Claim 2, wherein applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference comprises:

predicting an interval of increased interference based on the predetermined pattern; and

foregoing use of a selected frequency to communicate messages during the predicted interval.

9. The method according to Claim 1, wherein changing from a first interference mitigation scheme to a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference comprises transmitting a message from a first communications device to a second communications device to command use of the second interference mitigation scheme.

10. The method according to Claim 1, wherein changing from a first interference mitigation scheme to a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference comprises changing at least one of frequency hopping applied in the communications system, a message coding applied in the communications system and a message transmission scheduling applied in the communications system.

11. The method according to Claim 1, wherein the predetermined type of interference comprises one of a type of interference generated by a microwave generator and a type of interference generated by a wireless communications device.

12. The method according to Claim 1, wherein the predetermined pattern comprises a half-cycle pulse pattern associated with a microwave oven that occurs at a power line frequency, and wherein changing from a first interference mitigation scheme to a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference comprises changing from the first interference mitigation scheme to the second interference mitigation scheme if the detected interference exhibits a pulse pattern that occurs at a frequency sufficiently correlated to the power line frequency.

13. A communications system, comprising:

at least one communications device operative to communicate via a communications medium;

an interference detector that detects interference in the communications medium; and

an interference mitigation controller, operatively associated with the at least one communications device and responsive to the interference detector circuit, that causes the at least one communication device to change from using a first interference mitigation scheme to using a second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference.

14. The system according to Claim 13, wherein the interference mitigation controller causes the communications device to apply the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference.

15. The system according to Claim 14, wherein the interference mitigation controller causes the communications device to apply the second interference mitigation scheme according to a predetermined periodicity associated with the predetermined type of interference.

16. The system according to Claim 14, wherein the interference mitigation controller predicts an interval of interference based on the predetermined pattern.

17. The system according to Claim 16, wherein the interference controller causes the at least one communications device to forego transmission of messages during the predicted interval.

18. The system according to Claim 16, wherein the interference mitigation controller causes the at least one communications device to change coding applied to messages transmitted during the predicted interval.

19. The system according to Claim 16, wherein the interference mitigation controller causes the at least one communications device to forego communicating with a selected communications device during the predicted interval.

20. The system according to Claim 16, wherein the interference mitigation controller causes the at least one communications device to forego use of a selected frequency to communicate messages during the predicted interval.

21. The system according to Claim 13, wherein the interference mitigation controller causes a first communications device to transmit a message to a second communications device to command use of the second interference mitigation scheme.

22. The system according to Claim 13, wherein the interference mitigation controller causes a change in at least one of a frequency hopping applied by the at least one communications device, a message coding applied by the at least one communications device and a message transmission scheduling applied by the at least one communications device if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference.

23. The system according to Claim 13, wherein the predetermined type of interference comprises one of a type of interference generated by a microwave generator and a type of interference generated by a wireless communications device.

24. The system according to Claim 13, wherein the predetermined pattern comprises a half-cycle pulse pattern associated with a microwave oven that occurs at a power line frequency, and wherein the interference mitigation controller causes the at least one communications device to change from using the first interference mitigation scheme to using the second interference mitigation scheme if the detected interference exhibits a pulse pattern that occurs at a frequency sufficiently correlated to the power line frequency.

25. The system according to Claim 13, wherein the at least one communications device includes a communications circuit, and wherein at least one of the interference detector and the interference mitigation controller are operatively associated with the communications circuit.

26. The system according to Claim 25, wherein the interference detector circuit is responsive to the communications circuit to detect interference.

27. The system according to Claim 13:

wherein the at least one communications device comprises a plurality of communications devices;

wherein the interference detector comprises at least one interference detector circuit positioned at at least one of the plurality of communications devices; and

wherein the interference mitigation controller comprises at least one interference mitigation controller circuit positioned at at least one of the plurality of communications devices.

28. A communications system, comprising:

at least one communications device operative to communicate using first and second interference mitigation schemes;

means for detecting interference; and

means, responsive to the means for detecting interference, for causing the at least one communications device to change from using the first interference mitigation scheme to using the second interference mitigation scheme if the detected interference exhibits a pattern sufficiently correlated with predetermined pattern associated with a predetermined type of interference.

29. The system according to Claim 28, wherein the means for causing the at least one communications device to change from using the first interference mitigation scheme to using the second interference mitigation scheme comprises means for applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference.

30. The system according to Claim 29, wherein the means for applying the second interference mitigation scheme according to the predetermined pattern associated with the predetermined type of interference comprises:

means for predicting an interval of increased interference based on the predetermined pattern; and

means for performing at least one of the following:

foregoing transmission of messages during the predicted interval;

changing coding of messages transmitted during the predicted interval;

foregoing transmission of messages to a selected device of the communications system during the predicted interval; and

foregoing use of a selected frequency to communicate messages during the predicted interval.

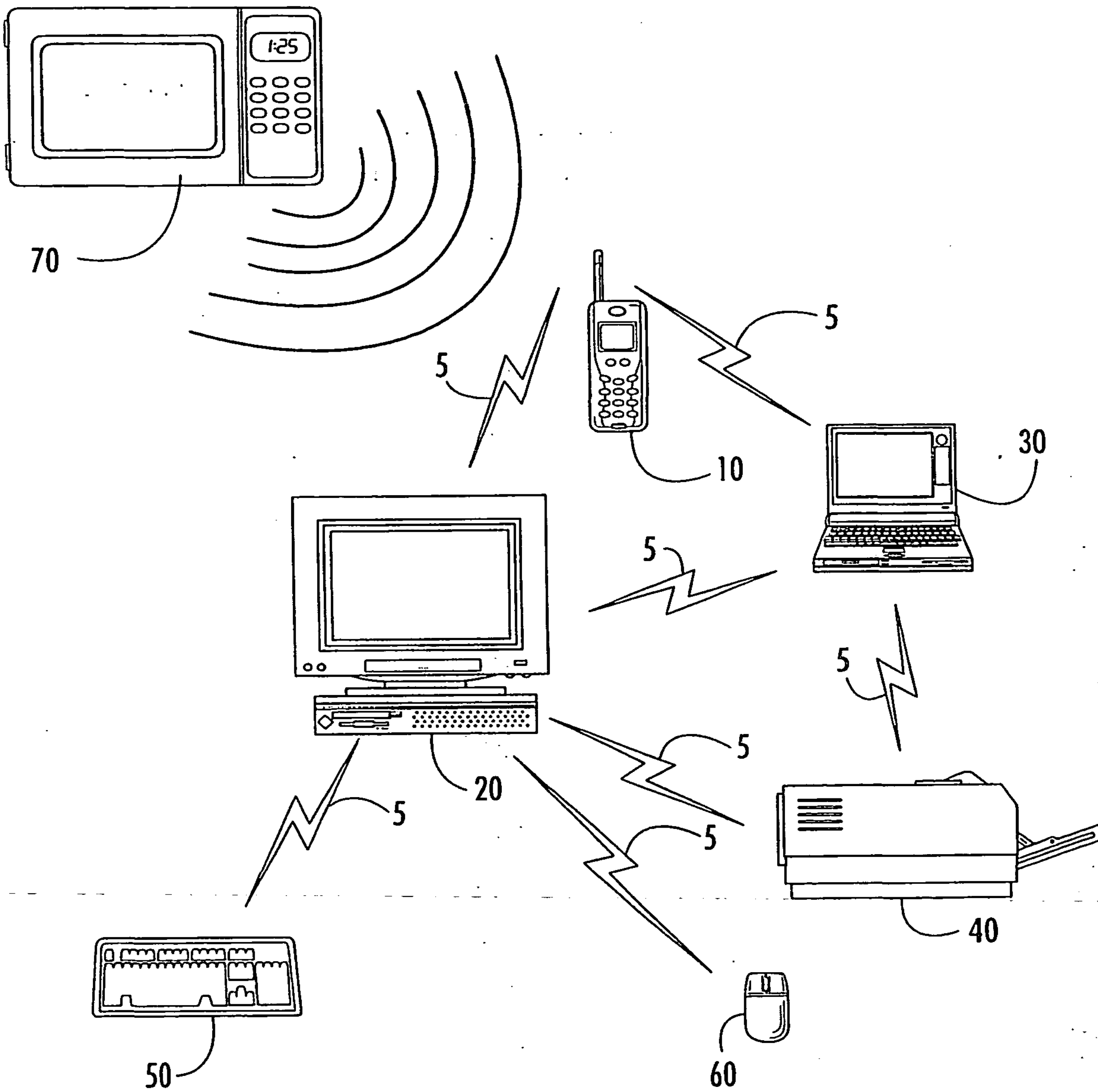


FIG. 1.
PRIOR ART

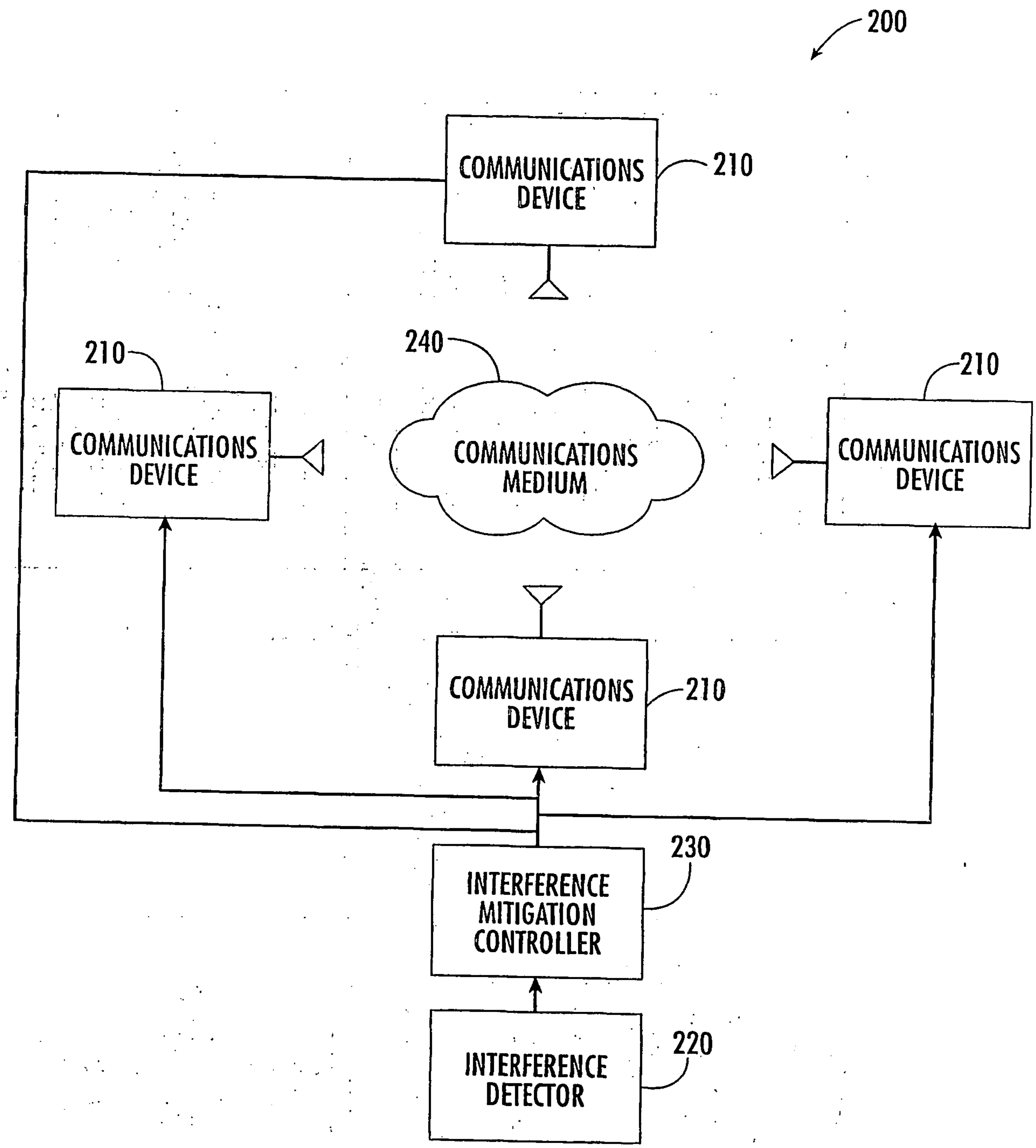

200
COMMUNICATIONS DEVICE
210
210
COMMUNICATIONS DEVICE
240
COMMUNICATIONS MEDIUM
210
COMMUNICATIONS DEVICE
COMMUNICATIONS DEVICE
210
230
INTERFERENCE MITIGATION CONTROLLER
INTERFERENCE DETECTOR
220

FIG. 2.

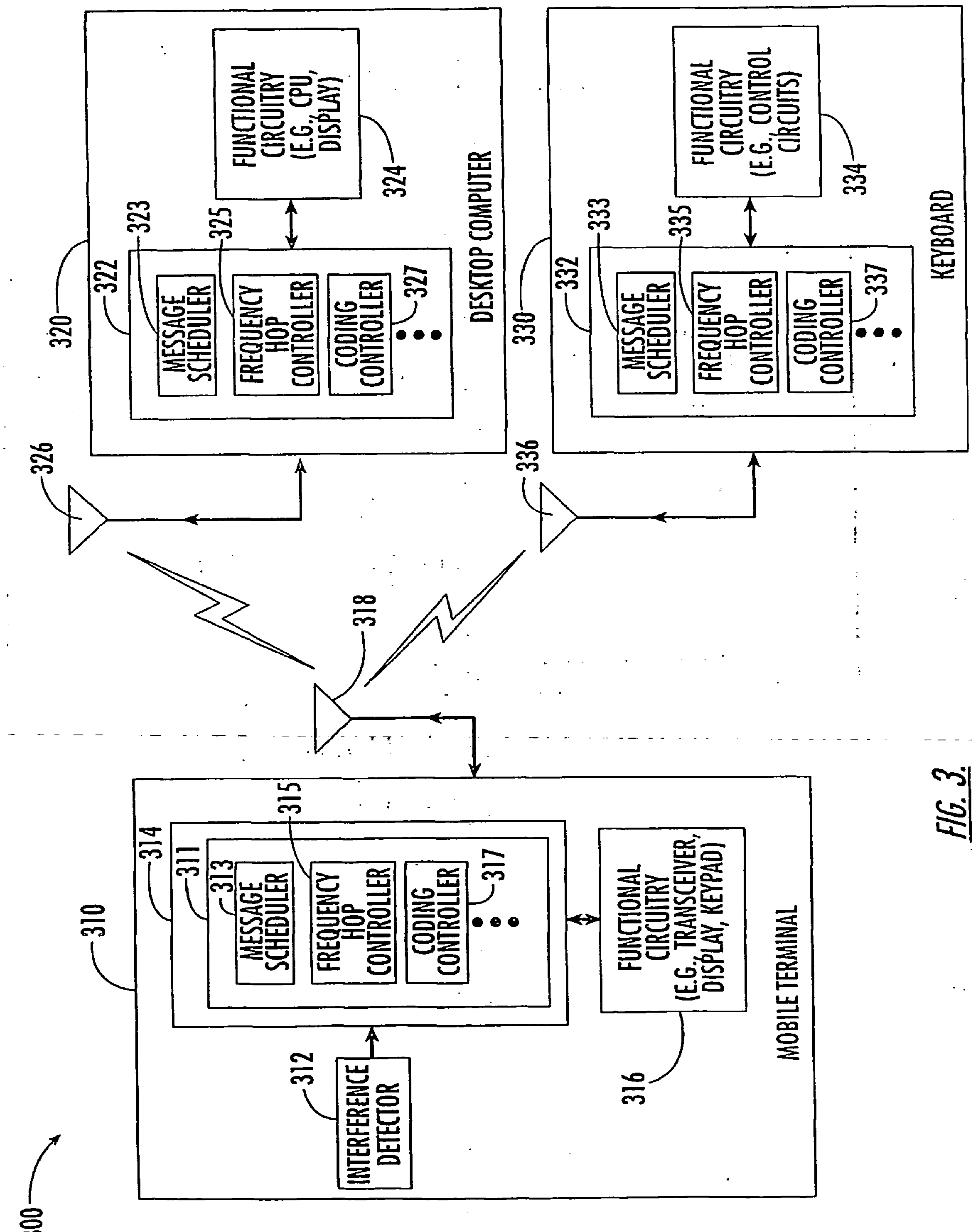

DESKTOP COMPUTER
320
322
323
MESSAGE SCHEDULER
325
FREQUENCY HOP CONTROLLER
CODING CONTROLLER
327
FUNCTIONAL CIRCUITRY (E.G., CPU, DISPLAY)
324
326
KEYBOARD
330
332
333
MESSAGE SCHEDULER
335
FREQUENCY HOP CONTROLLER
CODING CONTROLLER
337
FUNCTIONAL CIRCUITRY (E.G., CONTROL CIRCUITS)
334
336
318
MOBILE TERMINAL
310
314
311
313
MESSAGE SCHEDULER
315
FREQUENCY HOP CONTROLLER
CODING CONTROLLER
317
FUNCTIONAL CIRCUITRY (E.G., TRANSCEIVER, DISPLAY, KEYPAD)
316
312
INTERFERENCE DETECTOR
300

FIG. 3.

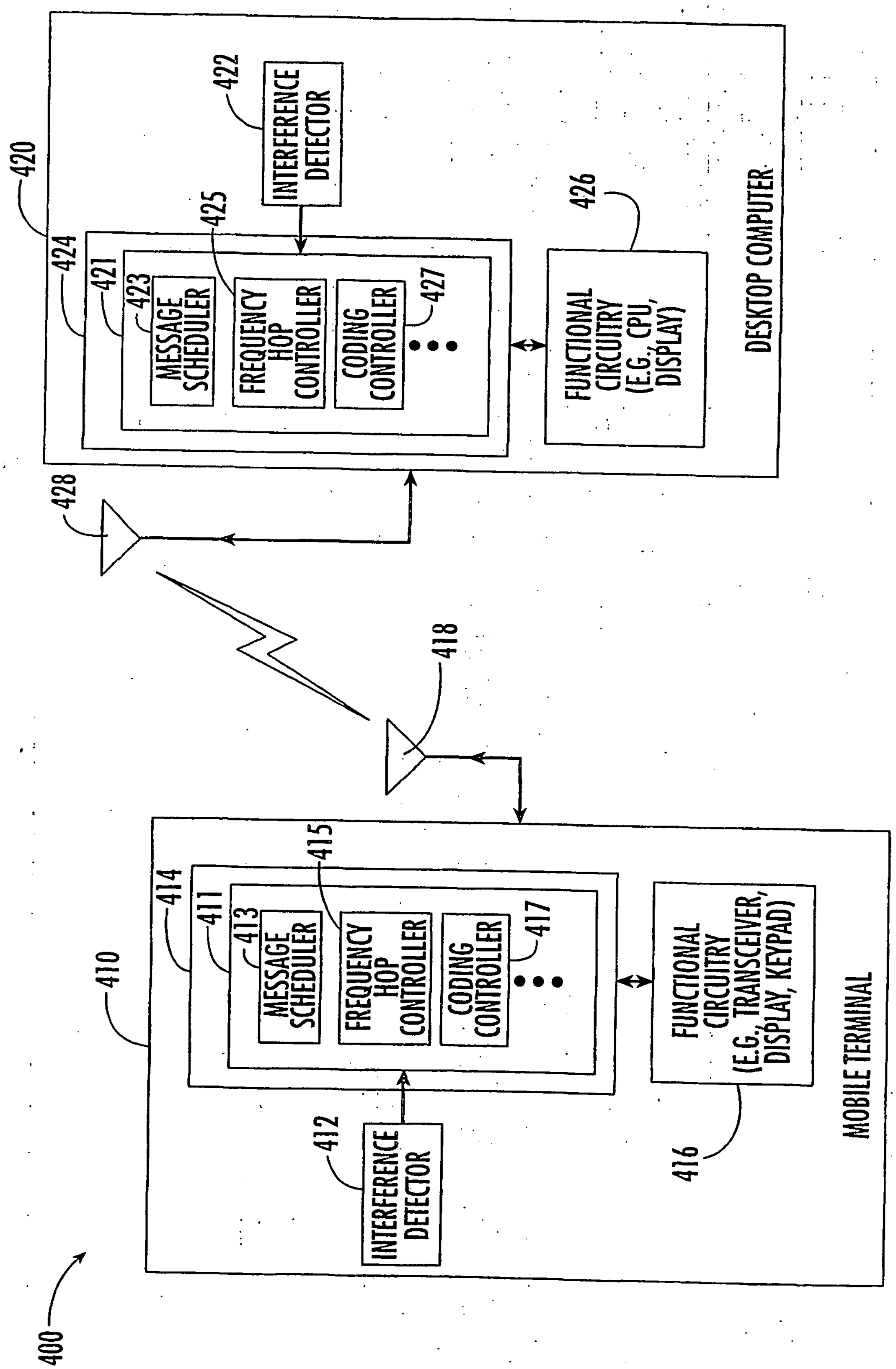
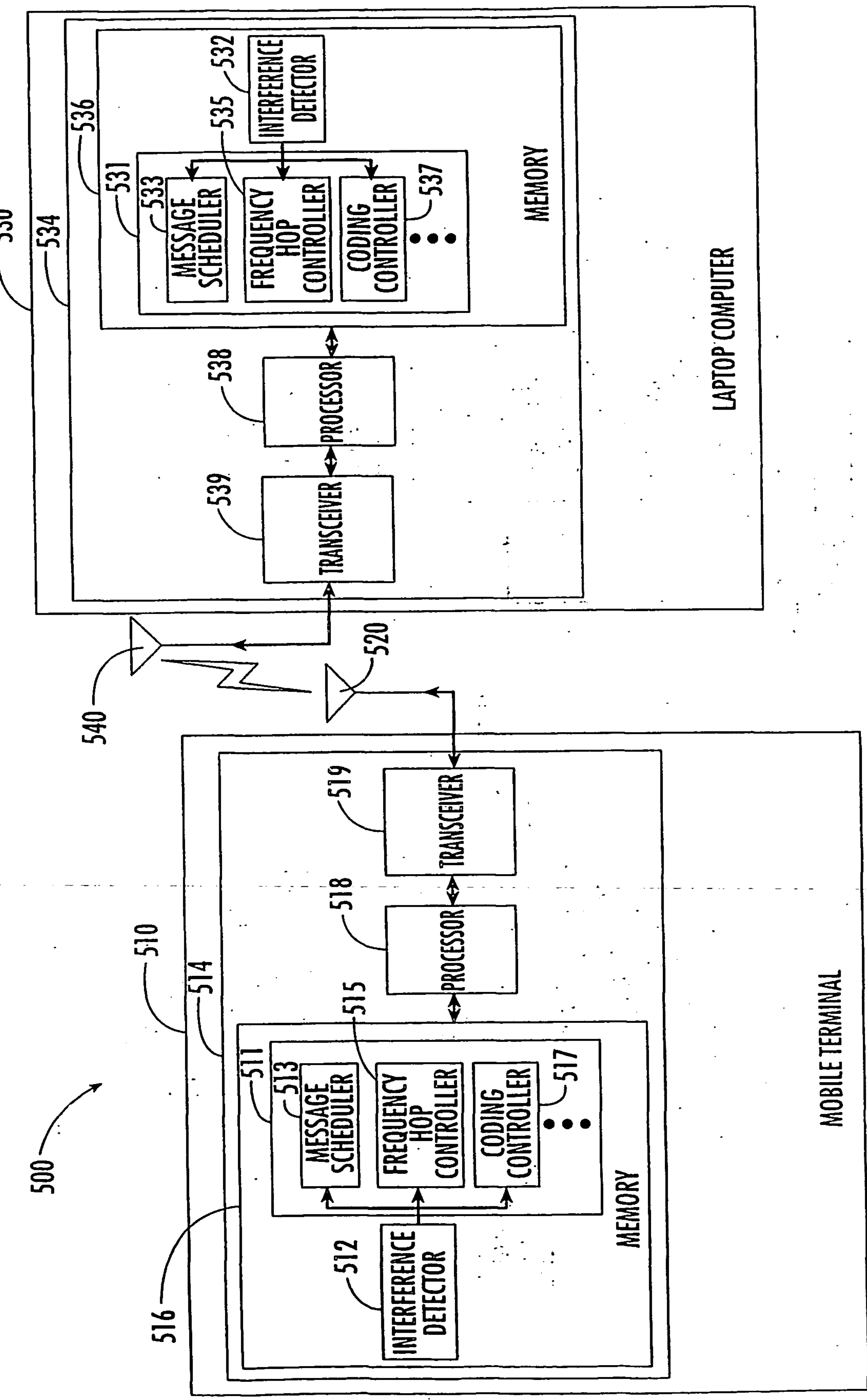

400
410
414
411
413
MESSAGE SCHEDULER
415
FREQUENCY HOP CONTROLLER
CODING CONTROLLER
417
412
INTERFERENCE DETECTOR
FUNCTIONAL CIRCUITRY (E.G., TRANSCEIVER, DISPLAY, KEYPAD)
416
MOBILE TERMINAL
418
428
420
424
421
423
MESSAGE SCHEDULER
425
FREQUENCY HOP CONTROLLER
CODING CONTROLLER
427
422
INTERFERENCE DETECTOR
FUNCTIONAL CIRCUITRY (E.G., CPU, DISPLAY)
426
DESKTOP COMPUTER

FIG. 4.



530
534
536
531
533
MESSAGE SCHEDULER
535
FREQUENCY HOP CONTROLLER
CODING CONTROLLER
537
532
INTERFERENCE DETECTOR
MEMORY
538
PROCESSOR
539
TRANSCEIVER
LAPTOP COMPUTER
540
520
510
514
511
513
MESSAGE SCHEDULER
515
FREQUENCY HOP CONTROLLER
CODING CONTROLLER
517
512
INTERFERENCE DETECTOR
MEMORY
516
518
PROCESSOR
519
TRANSCEIVER
MOBILE TERMINAL
500

FIG. 5.

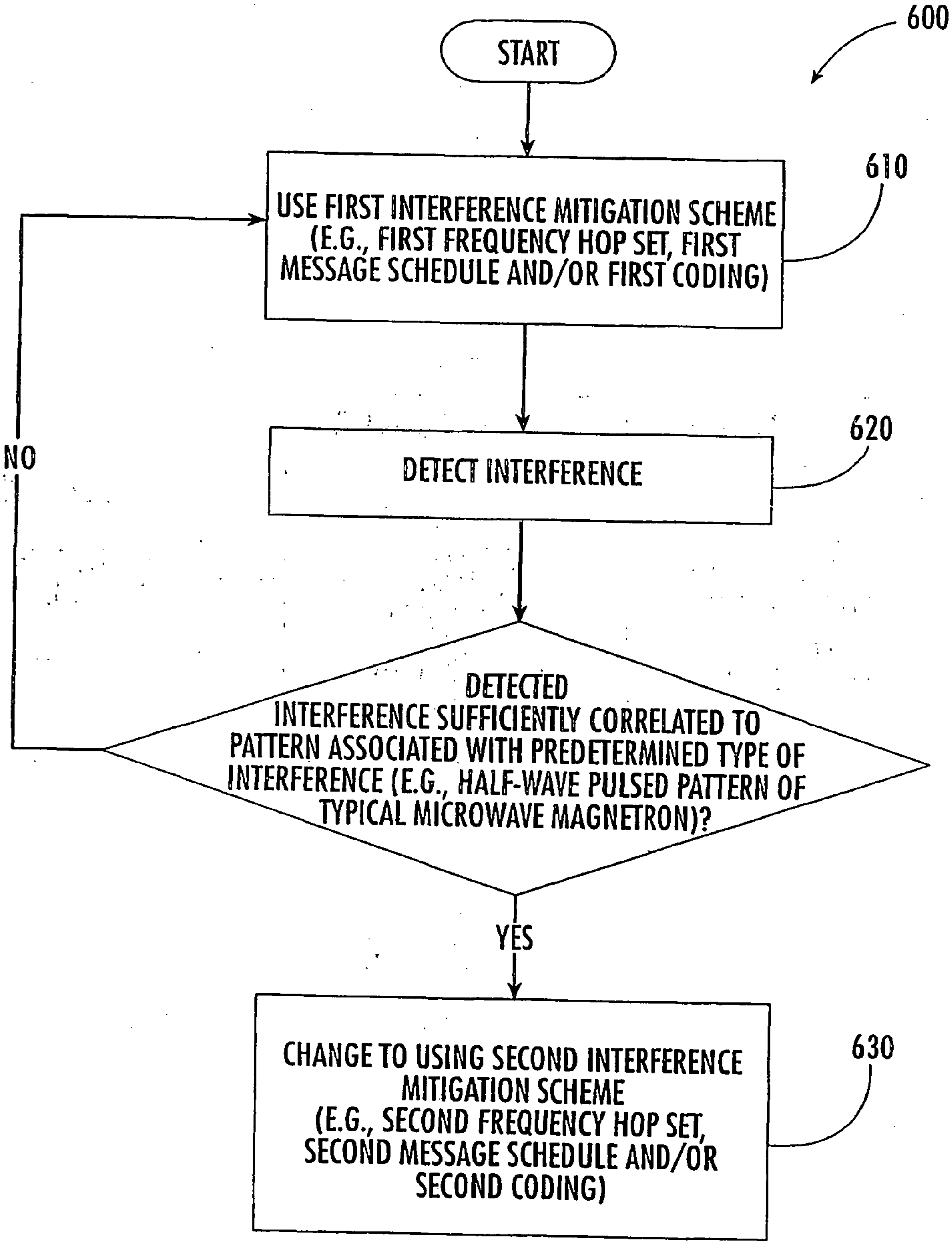

600
START
USE FIRST INTERFERENCE MITIGATION SCHEME (E.G., FIRST FREQUENCY HOP SET, FIRST MESSAGE SCHEDULE AND/OR FIRST CODING)
610
DETECT INTERFERENCE
620
NO
DETECTED INTERFERENCE SUFFICIENTLY CORRELATED TO PATTERN ASSOCIATED WITH PREDETERMINED TYPE OF INTERFERENCE (E.G., HALF-WAVE PULSED PATTERN OF TYPICAL MICROWAVE MAGNETRON)?
YES
CHANGE TO USING SECOND INTERFERENCE MITIGATION SCHEME (E.G., SECOND FREQUENCY HOP SET, SECOND MESSAGE SCHEDULE AND/OR SECOND CODING)
630

FIG. 6.

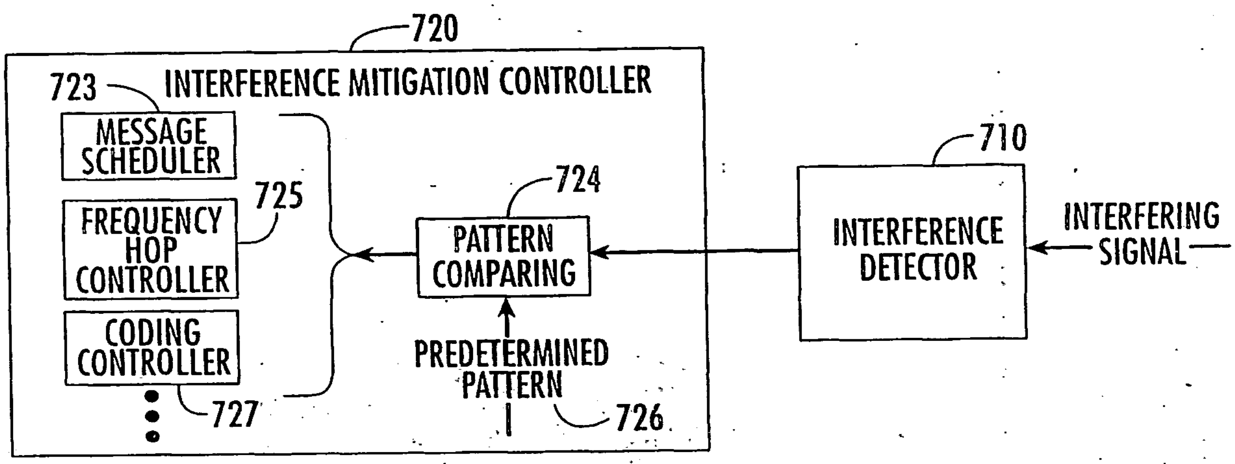

720
INTERFERENCE MITIGATION CONTROLLER
723
MESSAGE SCHEDULER
725
FREQUENCY HOP CONTROLLER
CODING CONTROLLER
727
724
PATTERN COMPARING
PREDETERMINED PATTERN
726
710
INTERFERENCE DETECTOR
INTERFERING SIGNAL

FIG. 7.

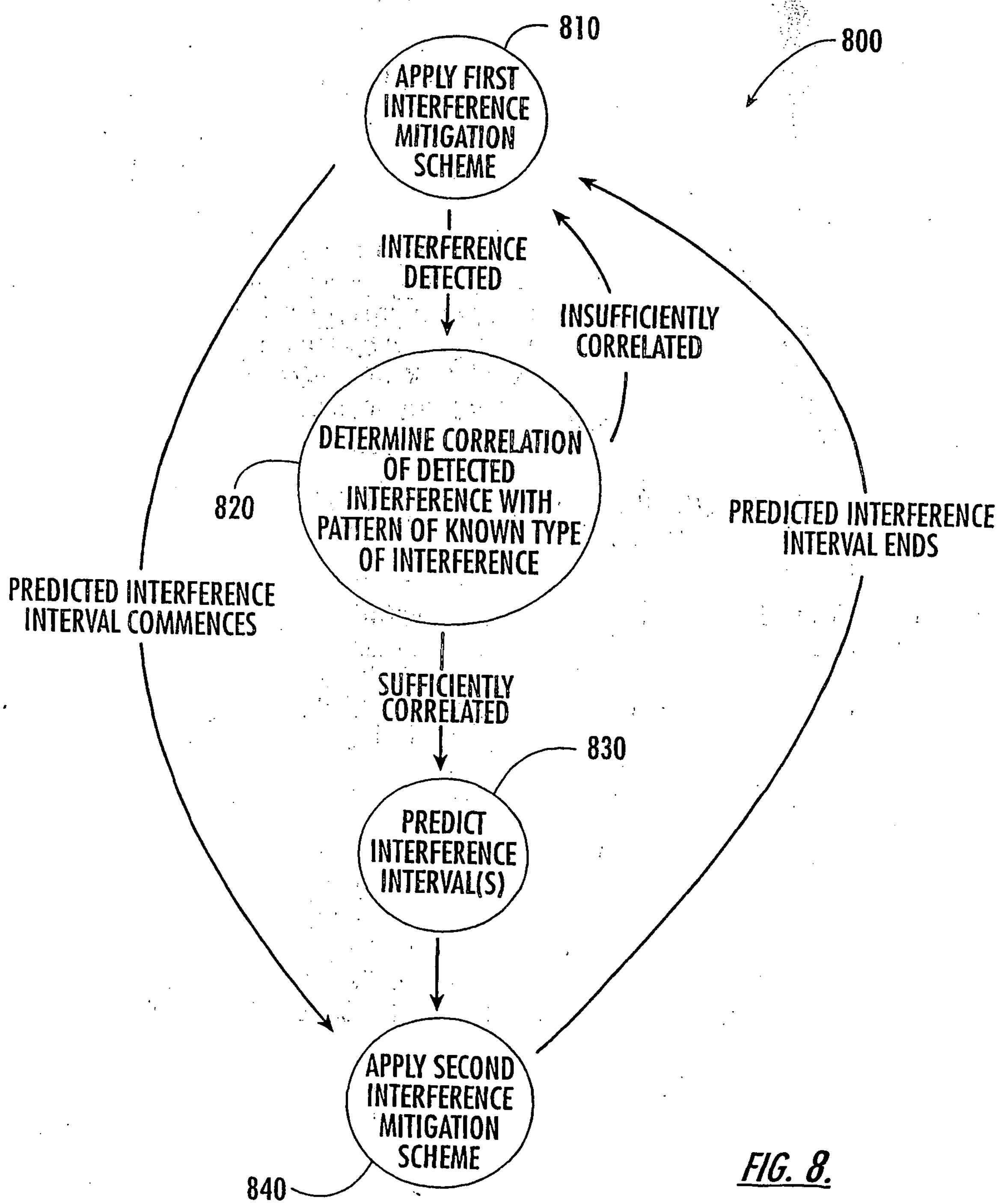
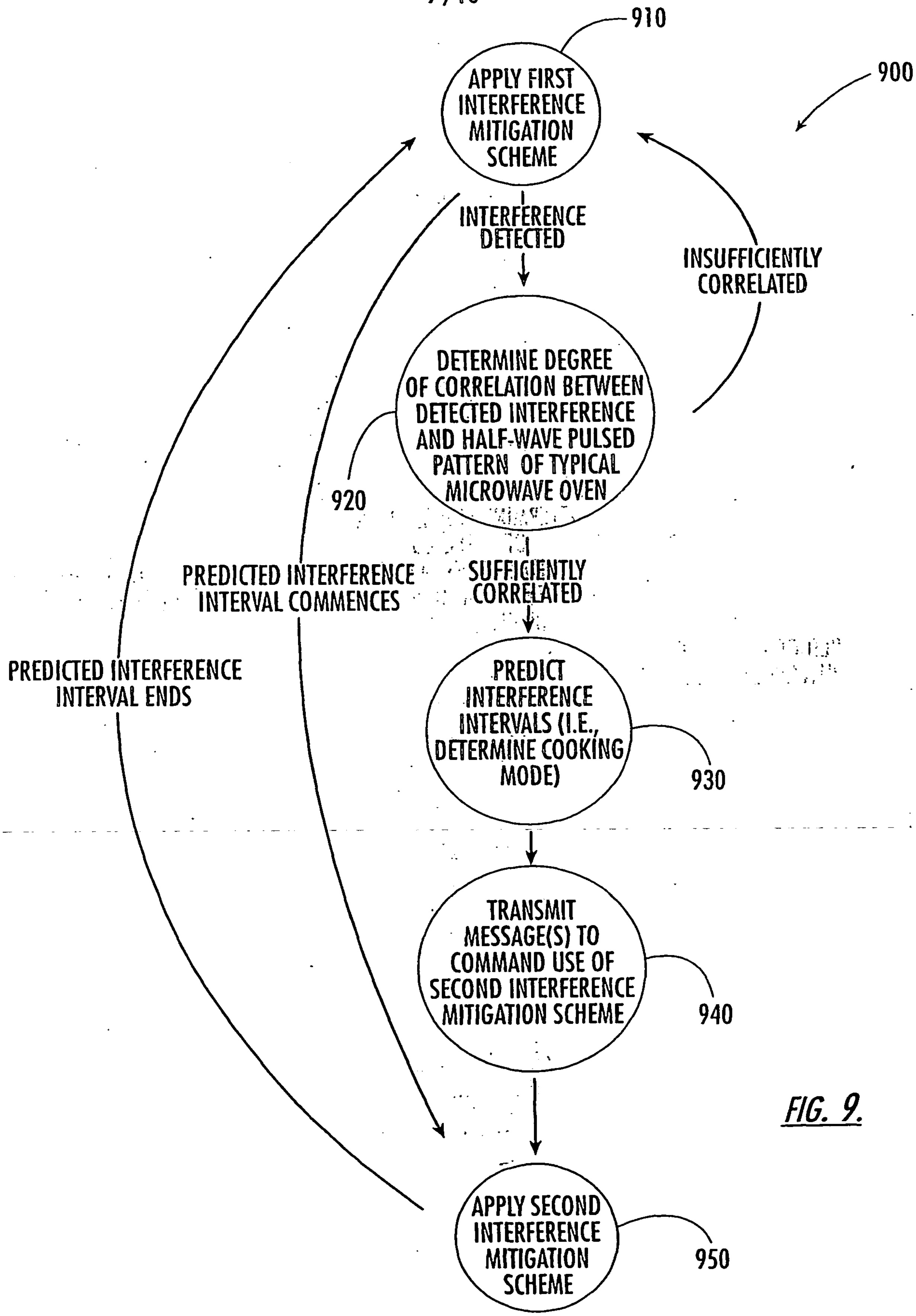

810
800
APPLY FIRST INTERFERENCE MITIGATION SCHEME
INTERFERENCE DETECTED
INSUFFICIENTLY CORRELATED
DETERMINE CORRELATION OF DETECTED INTERFERENCE WITH PATTERN OF KNOWN TYPE OF INTERFERENCE
820
PREDICTED INTERFERENCE INTERVAL ENDS
PREDICTED INTERFERENCE INTERVAL COMMENCES
SUFFICIENTLY CORRELATED
830
PREDICT INTERFERENCE INTERVAL(S)
APPLY SECOND INTERFERENCE MITIGATION SCHEME
840

FIG. 8.



910
900
APPLY FIRST INTERFERENCE MITIGATION SCHEME
INTERFERENCE DETECTED
INSUFFICIENTLY CORRELATED
DETERMINE DEGREE OF CORRELATION BETWEEN DETECTED INTERFERENCE AND HALF-WAVE PULSED PATTERN OF TYPICAL MICROWAVE OVEN
920
PREDICTED INTERFERENCE INTERVAL COMMENCES
SUFFICIENTLY CORRELATED
PREDICTED INTERFERENCE INTERVAL ENDS
PREDICT INTERFERENCE INTERVALS (I.E., DETERMINE COOKING MODE)
930
TRANSMIT MESSAGE(S) TO COMMAND USE OF SECOND INTERFERENCE MITIGATION SCHEME
940
APPLY SECOND INTERFERENCE MITIGATION SCHEME
950

FIG. 9.

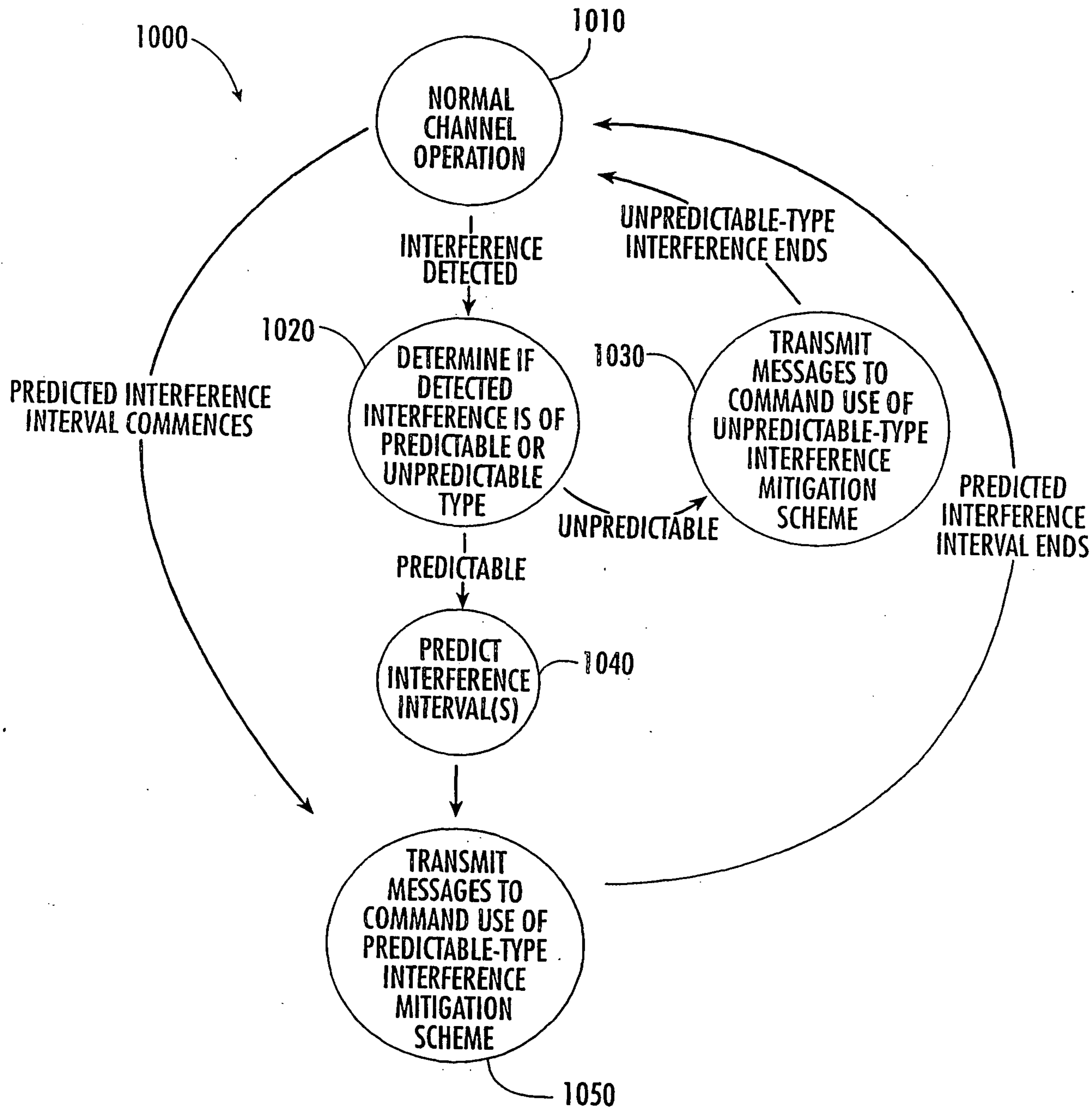

1000
1010
NORMAL CHANNEL OPERATION
INTERFERENCE DETECTED
UNPREDICTABLE-TYPE INTERFERENCE ENDS
1020
DETERMINE IF DETECTED INTERFERENCE IS OF PREDICTABLE OR UNPREDICTABLE TYPE
1030
TRANSMIT MESSAGES TO COMMAND USE OF UNPREDICTABLE-TYPE INTERFERENCE MITIGATION SCHEME
PREDICTED INTERFERENCE INTERVAL COMMENCES
UNPREDICTABLE
PREDICTED INTERFERENCE INTERVAL ENDS
PREDICTABLE
PREDICT INTERFERENCE INTERVAL(S)
1040
TRANSMIT MESSAGES TO COMMAND USE OF PREDICTABLE-TYPE INTERFERENCE MITIGATION SCHEME
1050

FIG. 10.